Erie-Niagara Basin

Sediment In Streams

ERIE-NIAGARA BASIN REGIONAL WATER RESOURCES PLANNING BOARD

THE NEW YORK STATE WATER RESOURCES COMMISSION

CONSERVATION DEPARTMENT • DIVISION OF WATER RESOURCES

ENB-5

A RECONNAISSANCE OF STREAM SEDIMENT IN THE ERIE-NIAGARA BASIN, NEW YORK

Prepared for the
Erie-Niagara Basin Regional Water Resources
Planning Board

by

R. J. Archer and A. M. La Sala, Jr.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
in cooperation with
THE NEW YORK STATE CONSERVATION DEPARTMENT
DIVISION OF WATER RESOURCES

STATE OF NEW YORK
CONSERVATION DEPARTMENT
WATER RESOURCES COMMISSION

Basin Planning Report ENB-5
1968

ERIE-NIAGARA BASIN REGIONAL WATER RESOURCES PLANNING BOARD

BOARD MEMBERS

	County	Representing
Frank Walkley, Chairman	Wyoming	Member-at-Large
Wendell W. Call, Vice-Chairman	Genesee	Agriculture
Robert F. Chrestensen, Secretary	Cattaraugus	Member-at-Large
Arthur J. Carlsen	Erie	Municipal Corporations
W. Kendall Jenkins	Wyoming	Recreation and Fishing
James P. McKenna	Erie	Public Water Supply
Arthur S. Merrow	Erie	Industry

FORMER BOARD MEMBERS

Richard F. Ball, Deceased April 1967	Erie	Public Water Supply
Lee I. Dickinson, Deceased September 1967	Erie	Industry

BOARD STAFF-DIVISION OF WATER RESOURCES-CONSERVATION DEPARTMENT

John C. McMahon..................................Regional Engineer
John A. Evans....................................Senior Hydraulic Engineer
Bruce G. Goodale.................................Senior Hydraulic Engineer
Paul J. Sausville................................Senior Hydraulic Engineer
Alvin Hollmer....................................Assistant Hydraulic Engineer
Gerald A. Strobel................................Assistant Sanitary Engineer
Myretta J. Zimpfer...............................Senior Stenographer
Patricia J. Bateman..............................Stenographer
Margaret A. Morrison.............................Stenographer

STATE OF NEW YORK CONSERVATION DEPARTMENT - WATER RESOURCES COMMISSION

MEMBERS

R. Stewart Kilborne......................Conservation Commissioner

J. Burch McMorran........................Commissioner of Transportation

Louis J. Lefkowitz.......................Attorney General

Hollis S. Ingraham, M. D. ....Commissioner of Health

Don J. Wickham...........................Commissioner of Agriculture and Markets

Ronald B. Peterson.......................Commissioner of Commerce

John J. Burns............................Office of Local Government

ADVISORY MEMBERS

David C. Knowlton........................Representing Industry

Leonard DeLalio..........................Representing Agriculture

Michael Petruska.........................Representing Sportsmen

Frank M. Dulan...........................Representing Political Subdivisions

Robert S. Drew...........................Secretary to the Commission

STATE OF NEW YORK CONSERVATION DEPARTMENT - DIVISION OF WATER RESOURCES

F. W. Montanari..........................Assistant Commissioner

N. L. Barbarossa.........................Assistant Director

E. L. Vopelak............................Director of Planning

UNITED STATES
DEPARTMENT OF THE INTERIOR
Stewart L. Udall, Secretary
GEOLOGICAL SURVEY

William T. Pecora........................Director

Ernest L. Hendricks......................Chief Hydrologist

George E. Ferguson.......................Regional Hydrologist

Garald G. Parker.........................District Chief

CONTENTS

ILLUSTRATIONS

TABLES

ACKNOWLEDGMENTS

This report has been prepared for the Erie-Niagara Basin Regional Water Resources Planning Board under the general guidance of Mr. R. C. Heath, former District Chief, and his successor, Mr. G. G. Parker, both of the United States Geological Survey's Albany, New York District Office.

The cooperation of the many local, State, and Federal agencies who have provided valuable data and assistance is gratefully acknowledged.

A RECONNAISSANCE OF STREAM SEDIMENT IN THE ERIE-NIAGARA BASIN, NEW YORK

by

R.J. Archer and A.M. La Sala, Jr.

ABSTRACT

This reconnaissance study of erosion and deposition of sediment in the Erie-Niagara basin indicates that the highest sediment yields, on the order of 1,000 tons per square mile per year, occur in streams that drain upland areas. In contrast, for example, from the lowland part of the Tonawanda Creek basin, the annual sediment yields are on the order of 100 tons per square mile per year. The estimated average annual sediment yields of streams in the basin range from 50 tons per square mile for Little Tonawanda Creek at Linden, to 1,500 tons per square mile for Cazenovia Creek at Ebenezer. These estimates are based on measured instantaneous sediment discharge at selected stream stations, the sediment loads of which ranged from 1,100 tons per year for Little Tonawanda Creek at Linden to 610,000 tons per year for Cattaraugus Creek at Gowanda. The accuracy of the estimates of average annual sediment discharge could be considerably improved by the collection of additional data. Nevertheless, the estimates are believed to be indicative of the magnitude of sediment yields and provide a general description of stream-sediment movement in the study area.

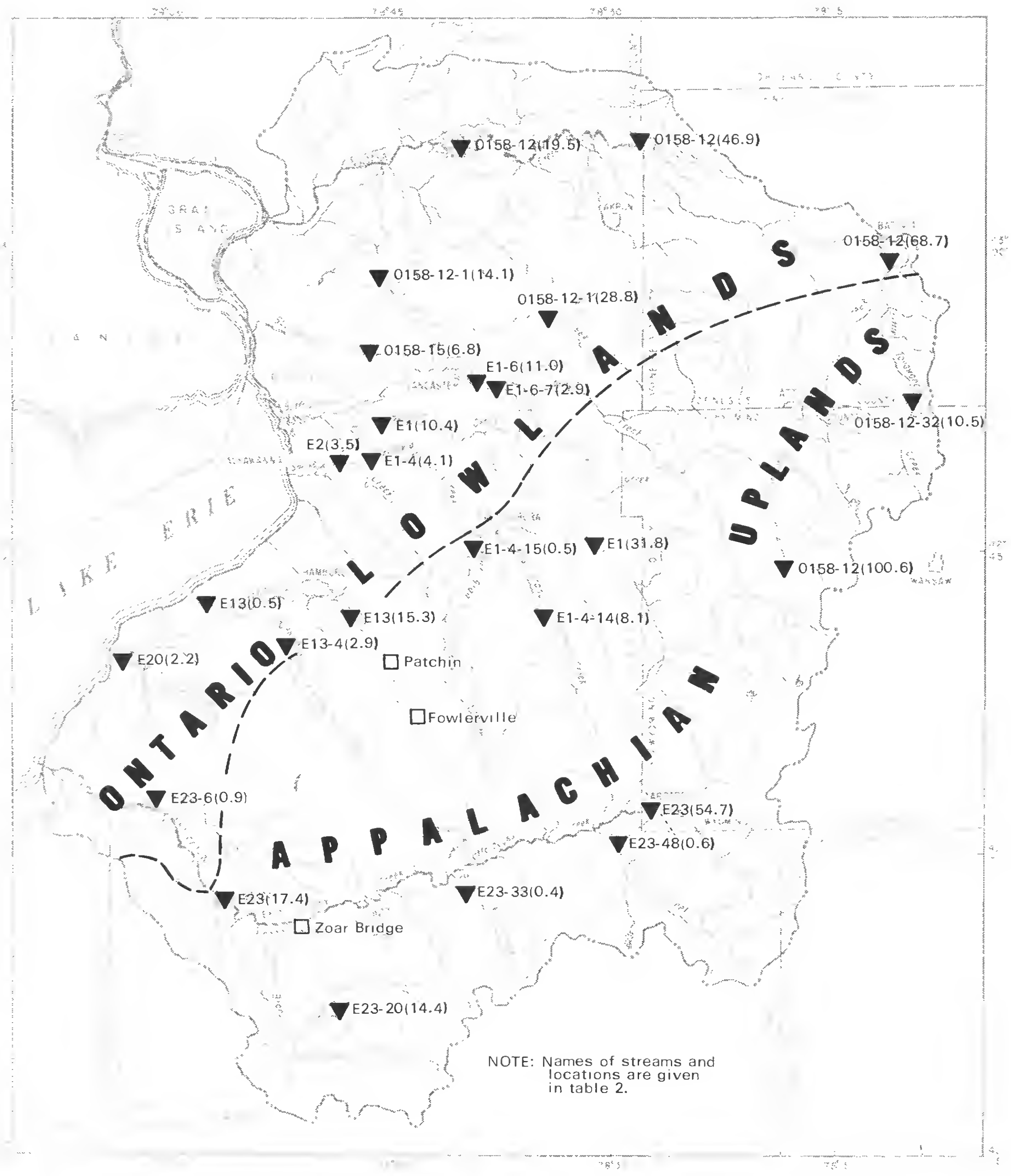
Peak suspended-sediment concentrations in the range of 2,600 to 5,300 ppm (parts per million) were observed at three stations in the Cattaraugus Creek basin, as well as at Buffalo Creek at Gardenville, Cazenovia Creek at Ebenezer, and Cayuga Creek near Lancaster.

INTRODUCTION

The development of water and land resources depends on many factors. One important factor is fluvial sediment which is defined as the solid material, mainly rock detritus, that is suspended in, transported by, or deposited by water (Colby and others, 1956, p. 37). Fluvial sediment, hereafter called simply sediment, is produced by the erosion of earth materials and can be a hindrance or limiting factor in developing water resources. The measurement of sediment transported by streams, therefore, provides information that can be useful in appraising both the effect of sediment on water-resources development and the extent of land losses arising from erosion. This report presents the results of one phase of the Geological Survey's investigation on behalf of the Erie-Niagara Board -- a reconnaissance of fluvial sediment in the Erie-Niagara basin.

Sediment loads were measured at 26 stations to provide a means of generally assessing variations in sediment transport in the area. At 15 of these stations sediment and streamflow data were sufficient to allow estimation of the annual sediment yields. The locations of all sediment-sampling stations are shown in figure 1.

Prior to this study, data on suspended-stream sediment in the study area were limited to the Buffalo River basin. The Buffalo Sewer Authority, as early as 1936, was including in their regular monthly observations the determination of total and suspended solids of the Buffalo River and of Cazenovia Creek near the Buffalo City line (Symons, G. E., Buffalo Sewer Authority, Oct. 19, 1937, written communication). In the same river basin, the Agricultural Research Service and the Soil Conservation Service initiated a program of sampling flood water for sediment in 1953 (Parsons and others, 1964). Samples were collected through 1963 for the purpose of determining what effects streambank stabilization works on Buffalo, Cayuga, and Cazenovia Creeks, the principal tributaries of the Buffalo River, had on the amount of suspended sediment carried into and deposited in Buffalo Harbor.



EXPLANATION

E23(54.7)

Sampling station and station number assigned in N.Y. State Conservation Department stream-numbering system.

Patchin

Site where bank erosion was measured.

Physiographic boundary

Basin boundary

Figure 1.--Location of suspended-sediment measuring stations.

SEDIMENT, ITS SOURCE AND CHARACTERISTICS

The term "sediment" as used in this report, includes only fragmental rock and soil material transported by, suspended in, or deposited by water within the present surface-water system. Stream sediments move either as suspended sediment or as bedload sediment. Suspended sediment is sediment that at any instant is maintained in suspension by upward components of turbulent flow or by molecular forces. A stream's ability to transport suspended sediment through turbulence increases, among other things, with velocity. Because velocity increases with streamflow, there is a general correlation between stream discharge and sediment concentration as shown in figure 2. The fragments in suspension are fine grained, that is, of sand size or smaller. Generally, particles of very fine sand are the coarsest that will remain in suspension because of stream turbulence. However, clay-size particles, as colloids, may remain suspended even in quiet water until flocculated or chemically precipitated.

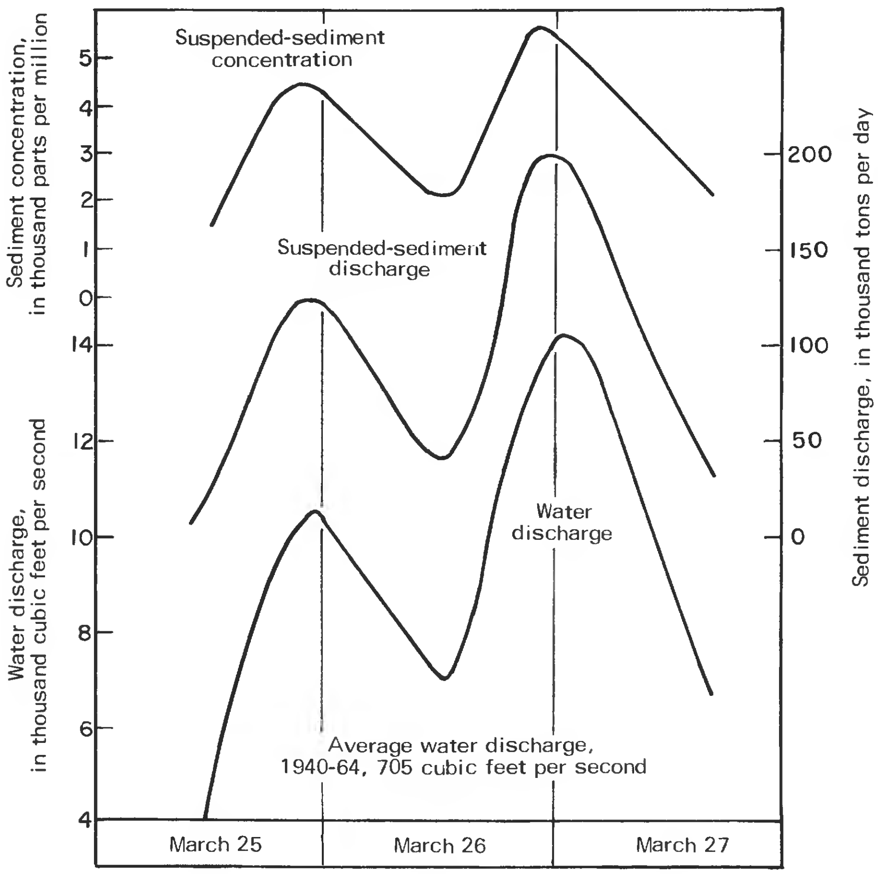


Figure 2.--Suspended-sediment concentration, suspended-sediment discharge, and water discharge in Cattaraugus Creek at Gowanda, March 25-27, 1963.

Bedload sediment, on the other hand, rolls or bounces along the streambed and is commonly much coarser than suspended sediment. A swiftly flowing stream can carry large boulders in this manner. Except for slowly flowing streams, such as the lower reaches of Tonawanda and Ellicott Creeks, the size of materials in the beds of area streams seems to be limited by the size of stones washed out of the glacial deposits. The largest materials present in quantity in glacial deposits are generally cobbles or boulders about a foot in diameter.

The bedload and suspended sediment moving in a thin zone above the streambed were not measured by the sampling techniques used in the study. This thin, basal zone will be referred to as the unmeasured zone. The suspended sediment moving above the unmeasured zone was sampled by the techniques used in the study, and this zone is referred to as the measured zone.

The land surface and stream channels contribute sediment in different ways. Part of the sediment is derived from sheet erosion of the land surface. Raindrops falling on the land loosen soil particles, which may eventually move into rills and be carried downslope by raindrop splash and by running water. The small tributary streams draining the uplands are generally downcutting their channels, extending them headward, and widening their valleys, while the major streams, such as Cattaraugus and Buffalo Creeks, are cutting laterally and headward into glacial deposits and old stream terrace deposits. This channel erosion provides an additional source of sediment to that derived from the land surface.

QUANTITATIVE DETERMINATION OF SEDIMENT AT MEASURING STATIONS

Suspended-sediment measurements were made at gaging stations and other streamflow stations where stage-discharge relations were known. Emphasis was placed on obtaining measurements during storm runoff when both the sediment concentration and load would be greatest. (See figure 2.) The measurements were computed by the following method. The sediment concentration was determined by sampling the stream water and analyzing in the laboratory for its sediment concentration. The water discharge (streamflow) at the time of sampling was determined from the stage-discharge rating. The instantaneous sediment discharge then was computed as the product of the sediment concentration and water discharge. In order to obtain some measure of the size of suspended sediment carried by the streams, particle-size determinations were made on selected samples collected from Cattaraugus Creek at Gowanda and Tonawanda Creek at Batavia.

Results of suspended-sediment measurements (values of suspended-sediment concentration and discharge) and of particle-size analyses are given in tables 3 and 4.

For gaging stations at which sufficient sediment-discharge and streamflow data were available, the average annual sediment discharge was estimated by a modification of a method used by Miller (1951). This modified method is based on both the long-term streamflow duration curves and on sediment-transport curves (graphs of suspended-sediment discharge plotted against water discharge). The following assumptions are made in using this method (Wark and others, 1961):

1. The relationship of the instantaneous sediment discharge to concurrent water discharge is similar to the relationship for daily values of sediment and water discharge.

2. The relationship of sediment discharge to streamflow existing during the period of field measurements represents the long-term relationship.

3. Water-discharge records, as summarized in duration tables, represent the long-term flow characteristics of the stream.

Sediment-transport curves were developed for measuring stations where stage-discharge relationships had been established. Figure 3 is the suspended-sediment transport curve for Cattaraugus Creek at Gowanda. To develop such a curve, the measured values of suspended sediment were plotted on logarithmic paper against the concurrent values for water discharge. This plot was then broken into logarithmically equal intervals of water discharge, and an average taken of all values of suspended sediment and

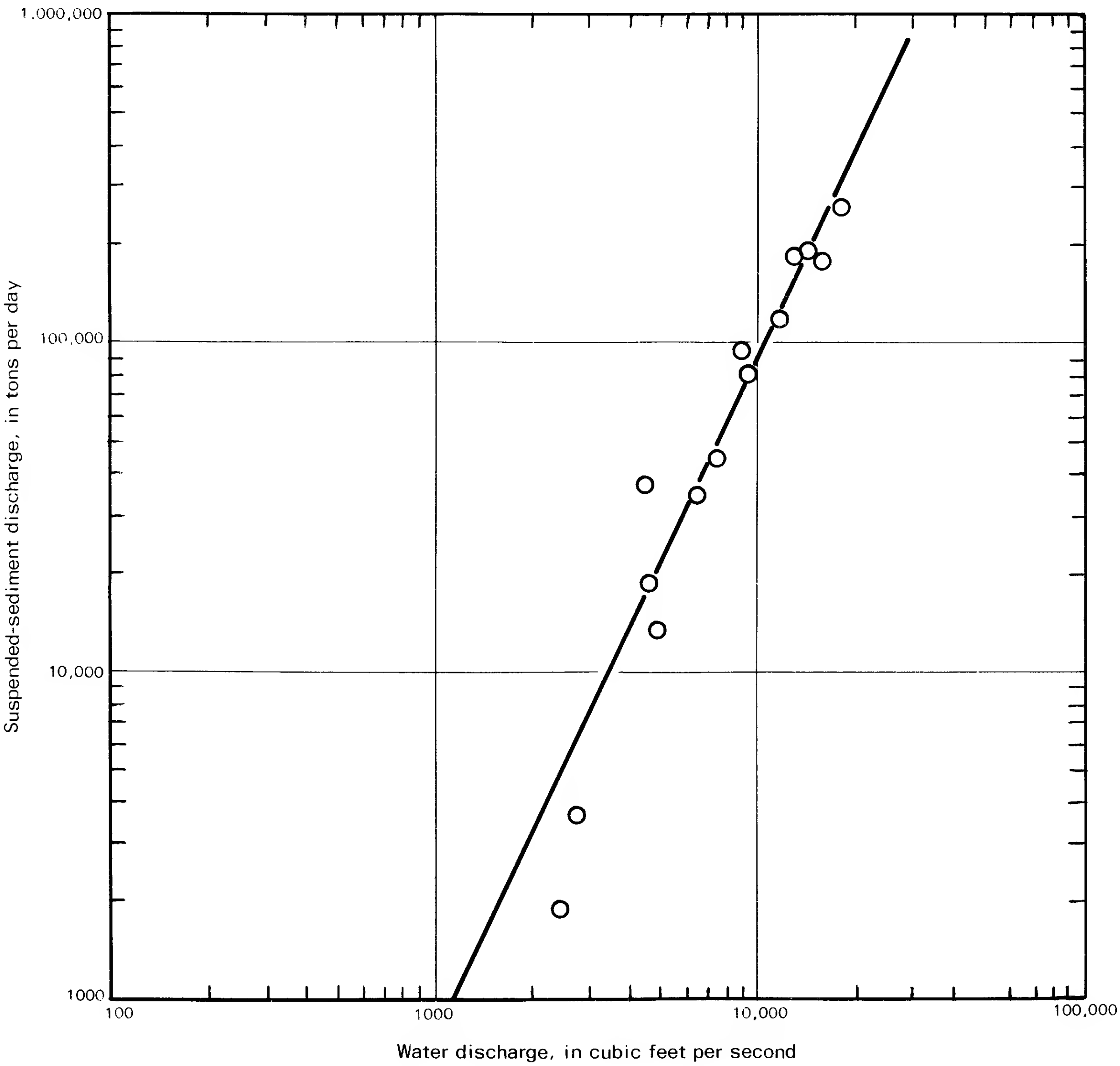


Figure 3.--Suspended-sediment transport curve for Cattaraugus Creek at Gowanda.

water discharge that fell within each interval. Finally, the average interval value was plotted and a sight-fitted straight line drawn through the average interval points to produce the suspended-sediment transport curve.

The next step in the computation of the estimated annual sediment discharge is to subdivide the long-term flow-duration curve into several intervals. As a large percentage of the sediment discharge occurs during a small percentage of the time, smaller intervals are used in the high discharge part of the curve. The intervals used for all sites are indicated in table 1, which is the computation sheet for Cattaraugus Creek at Gowanda. The mid-ordinate of each interval was taken from the sediment-transport

Table 1.--Computation of average annual sediment discharge, Cattaraugus Creek at Gowanda

Percent limits	Interval (percent)	Mid-ordinate (percent)	Water discharge (cfs)	Suspended-sediment discharge (tons/day)	Col. 2 times col. 5
0.0-0.25	0.25	0.125	12,800	166,000	415
0.25-0.75	.50	.50	7,600	54,500	272.5
0.75-1.5	.75	1.125	5,350	25,500	191.2
1.5-2.5	1.0	2.0	4,080	14,900	149
2.5-4.5	2	3.5	3,000	7,400	148
4.5-8.5	4	6.5	2,080	3,400	136
8.5-15	6.5	11.75	1,390	1,450	94.2
15-25	10	20	910	600	60
25-35	10	30	625	265	26.5
35-45	10	40	460	136	13.6
45-55	10	50	350	75	7.5
55-75	20	65	235	32	6.4
75-95	20	85	131	9.2	1.8
95-100	5	97.5	76	2.9	.1
Totals	100				1,521.8

Average annual suspended-sediment discharge = 365 x 1,520 = 555,000 tons

Add estimated 10 percent for bedload.................... 55,500 tons

610,500

Average annual sediment discharge (rounded).............. 610,000 tons

Drainage area is 432 square miles, therefore, average annual sediment discharge is.......................... 1,400 tons per square mile

curve to determine the equivalent suspended-sediment discharge value. This value was multiplied by the interval percentage (the percentage of the total interval represented by each individual interval). The total of all intervals is the estimated average daily suspended-sediment discharge. Multiplying the total interval figure by 365 produces the estimated annual suspended-sediment discharge. The suspended-sediment sampling techniques do not sample sediment moving in the unmeasured zone. For the basis of this reconnaissance study, the sediment transported in the unmeasured zone was estimated as 10 percent of the measured, annual suspended-sediment discharge. Wark and others (1961) estimated the bedload in the Potomac River basin as equivalent to 10 percent of the suspended-sediment load. They indicate that other investigators used the same estimate also. Keller and Gilbert (1966, p. 11-12) estimated the bedload in the Genesee River basin by the Schoklitsch formula (Colby and Hembree, 1955, p. 55-56) and the Meyer-Peter formula, and they found that an estimate of 10 percent was of the correct magnitude. Therefore, in this report, the annual suspended-sediment discharges that were computed were increased by 10 percent to obtain an estimate of the annual sediment yields.

Although the basic assumptions are substantially correct for most sites for which calculations were made, some error is inherent in the methods used in this investigation. More extensive sampling would improve the accuracy. Nevertheless, the estimates are believed to be indicative of the magnitude of sediment yields and provide a general description of stream-sediment movement in the study area.

VARIATION OF SEDIMENT CHARACTERISTICS

AREAL VARIATIONS

The amount of sediment carried by streams in the Erie-Niagara basin varies greatly because of variations in geology, topography, and land use. An estimated 1,100 tons of sediment per year is carried by Little Tonawanda Creek past Linden; whereas, Cattaraugus Creek carries as much as an estimated 610,000 tons per year past Gowanda. Table 2 gives the computed annual sediment discharge for 15 stations at which stream gages are maintained by the Geological Survey (fig. 1). The sediment discharge is also expressed as unit yield in tons per square mile of drainage basin in order to compare more conveniently the sediment yields of basins of different sizes.

If the 10 stations with 10 or more measurements are considered to represent a reasonable comparison of sediment yields in the basin, they define an area of comparatively high sediment yield as shown in figure 4.

This area, in general, coincides with the Appalachian Uplands where slopes and stream gradients are steep and an ample supply of easily erodible glacial materials is available. The average annual sediment yields of Cattaraugus Creek between Arcade and Gowanda, Buffalo Creek between Gardenville and Wales Hollow, Cazenovia Creek upstream from Ebenezer, Cayuga Creek upstream from Lancaster, and Buttermilk Creek are particularly high, as can be seen from table 2 and figure 4. In hilly terrain, such as is drained by these streams, comparatively high sediment yields should be expected because of the high rates of sheet erosion and the active downcutting and headcutting of the tributary streams. However, annual yields even in hilly terrains, considerably exceeding 500 tons per square mile are unusual in the northeastern United States (Rainwater, 1961). The streams having high-sediment yields flow through valleys in which lake deposits of clay and silt lie at altitudes considerably above stream levels. Erosion of these lake deposits probably is responsible for the high-sediment yields.

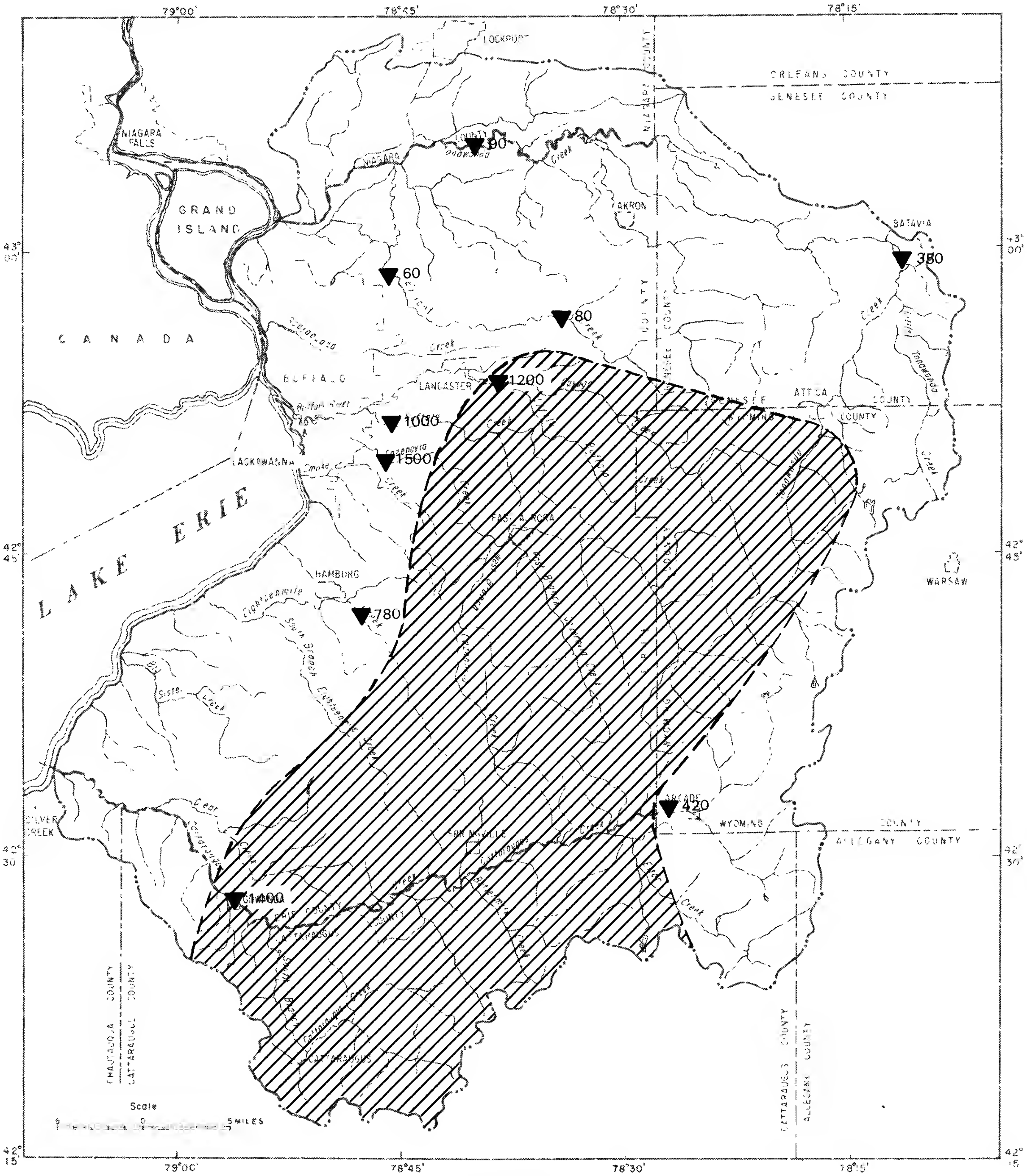
In contrast to the uplands, the sediment yields from basins in the Erie-Ontario Lowlands are comparatively low, principally because of the low slopes and stream gradients. The annual sediment discharges for stations on Tonawanda Creek (table 2) suggest a net deposition of sediment between Batavia and Rapids. This suggested deposition probably does not actually occur, particularly in a long-term sense. The computed sediment discharges at Rapids and Alabama may be subject to large errors: (1) in estimating the material moving in the unmeasured zone; (2) arising from the samples collected at the site not being representative of the long-term sediment discharge; and (3) because of natural diversions that occur in Tonawanda Creek basin at high flows. For instance, the discharge of Tonawanda Creek at Rapids is affected by a diversion into Black and Ransom Creeks, as is explained by Harding and Gilbert (1968).

Table 2.--Computed annual average sediment discharges of streams in the Erie-Niagara basin

Sampling point mileage index number	USGS station number	Stream and location	Drainage area (sq mi)	Number of measurements	a/ Computed annual average sediment discharge: Tons	a/ Computed annual average sediment discharge: Tons per sq mi
E23(54.7)	2134.1	Cattaraugus Creek near Arcade	78.4	11	33,000	420
E23-48(0.6)	2134.2	Elton Creek at The Forks	71.6	10	--	--
E23-33(0.4)	2134.5	Buttermilk Creek near Springville	29.3	8	38,000	1,300
E23-20(14.4)	2134.9	South Branch Cattaraugus Creek near Otto	25.4	5	--	--
E23(17.4)	2135	Cattaraugus Creek at Gowanda	432	14	610,000	1,400
					--	--
E23-6(0.9)	2140.1	Clear Creek near Iroquois	55.8	3	--	--
E20(2.2)	2140.6	Big Sister Creek at Evans Center	48.4	1	--	--
E13(15.3)	2142	Eighteenmile Creek at North Boston	37.2	14	29,000	780
E13-4(2.9)	2142.3	South Branch Eighteenmile Creek at Eden Valley	36.3	1	--	--
E13(0.5)	2142.4	Eighteenmile Creek near Highland-on-the-Lake	119	2	--	--
E2(3.5)	2142.5	Smoke Creek at Lackawanna	14.6	1	--	--
E1(31.8)	2144	Buffalo Creek near Wales Hollow	80.1	8	20,000	250
E1(10.4)	2145	Buffalo Creek at Gardenville	144	62	150,000	1,000
E1-6-7(2.9)	2149.8	Little Buffalo Creek near East Lancaster	23.9	2	--	--
E1-6(11.0)	2150	Cayuga Creek near Lancaster	94.9	56	110,000	1,200
E1-4-15(0.5)	2152.5	West Branch Cazenovia Creek at East Aurora	58.6	4	--	--
E1-4-14(8.1)	2153.5	East Branch Cazenovia Creek at South Wales	38.0	7	--	--
E1-4(4.1)	2155	Cazenovia Creek at Ebenezer	134	55	200,000	1,500
0158-15(6.8)	2162	Scajaquada Creek at Buffalo	15.9	4	--	--
0158-12(100.6)	2164	Tonawanda Creek near Johnsonburg	23.6	5	5,900	250
0158-12-32(10.5)	2165	Little Tonawanda Creek at Linden	22.1	7	1,100	50
0158-12(68.7)	2170	Tonawanda Creek at Batavia	171	20	60,000	350
0158-12(46.9)	2175	Tonawanda Creek at Alabama	231	6	37,000	160
0158-12(19.5)	2180	Tonawanda Creek at Rapids	352	12	32,000	90
0158-12-1(28.8)	2184.5	Ellicott Creek at Mill Grove	40.7	13	3,100	80
0158-12-1(14.1)	2185	Ellicott Creek at Williamsville	72.4	12	4,300	60

a/ Includes 10 percent of the calculated suspended-sediment discharge for bedload estimate

The variation in precipitation and in resultant runoff also contributes somewhat to the variation in sediment yields. The average annual precipitation in the study area ranges from 44 to 31 inches and the runoff from about 25 to 15 inches, decreasing generally from south to north (Harding and Gilbert, 1968). The greater precipitation provides greater runoff, which results in relatively high-stream discharge and a high rate of sediment transport.



EXPLANATION

▼90

Station with 10 or more sediment-discharge measurements; figure gives computed annual sediment discharge, in tons per square mile of drainage basin.

Area of probable high annual sediment yield (greater than 1000 tons per square mile).

Basin boundary

Figure 4.--Area of probable high annual sediment yield.

TEMPORAL VARIATIONS

Sediment yields vary from time to time (temporal variations) as well as from place to place. Previous discussions are based on the estimated average-annual sediment discharge, but the sediment discharge at any time may depart considerably from the average. For example, 10 years of measured annual sediment yields for the Cuyahoga River at Independence, Ohio, indicate a range in annual yields from 19 to 156 percent of the average. The annual sediment yield for 1959 is closest to equaling the average for the 10-year period as shown in figure 5. During these same 10 years the water discharge ranged from 50 to 139 percent of the 10-year average. Generally, years having a high-water discharge also have high-sediment discharge. How well these variations compare with variations which may occur in the Erie-Niagara basin is not known, but similar variations can be expected on the basis of data collected for various streams in the northeastern United States over a period of years.

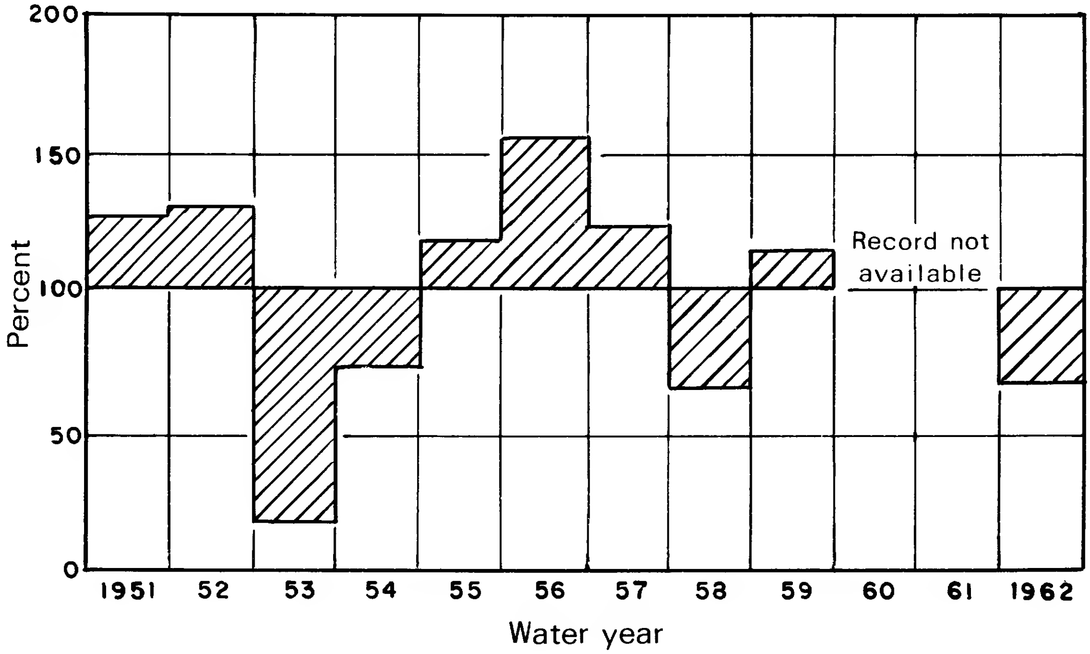


Figure 5.--Suspended-sediment discharge of Cuyahoga River at Independence, Ohio, shown annually as percent variation from a 10-year average.

The seasonal or monthly variations are even more pronounced than the annual. For the same 10 years of record for the Cuyahoga River, sediment discharges for October range from 0.5 to 949 percent of the October average, and sediment discharges for March range from 8 to 200 percent of the March average.

The conditions prior to a period of high flow control, in part, the temporal variations in sediment discharge. The prior conditions affect sediment discharge by controlling, to a degree, both streamflow and the

supply of sediment. These conditions tend to follow seasonal patterns. In summer, vegetation consumes most of the soil moisture and reduces storm runoff, thus, decreasing the quantity of sediment transported by streams. In the fall, the soil is generally dry and will absorb much of the precipitation, thereby reducing runoff. In winter, runoff is comparatively low because much of the precipitation is stored on the surface as snow, which also forms a protective cover on the land surface. However, the "normal" condition of high spring streamflow and sediment discharge does not always prevail. A substantial proportion of the annual sediment discharge of a stream can occur at any time from the runoff produced by a single intense or large-volume storm. Sediment discharges during such runoff events have been known to exceed "normal" annual sediment discharges. The effect of rising and falling water discharges on sediment discharge is shown in figure 2.

PARTICLE SIZE

The particle-size distributions of suspended sediment in six samples of water are given in table 3. The materials in the suspended sediment are mainly of the clay and silt sizes. At high flows, clay makes up more than half of the suspended sediment in Tonawanda Creek at Batavia and about one-third the suspended sediment in Cattaraugus Creek at Gowanda. The general differences in size distribution for sediments sampled in these two streams probably arise from a difference in the character of the earth materials being eroded and from a difference in hydraulic conditions.

The waters of both streams are turbid and visual inspection of the other large streams in the area at high flow indicates a similar turbid condition. The high-clay content of the water, particularly Tonawanda Creek at Batavia, may prove to be a serious problem in reservoirs constructed for recreational purposes because of the high turbidity of the water to be stored. Water with a high-clay content also would require treatment for use in a public supply.

Table 3.--Particle-size analyses of suspended sediment from Cattaraugus Creek at Gowanda, and Tonawanda Creek at Batavia

(Methods of analysis: B, bottom withdrawal tube; C, chemically dispersed; M, mechanically dispersed; N, in native water; S, sieve; W, in distilled water)

Date of collection	Time (24-hour)	Discharge (cfs)	Water temperature (°F)	Suspended sediment: Concentration of sample (ppm)	Percent finer than indicated size, in millimeters: Sedimentation diameters 0.002	0.004	0.008	0.016	0.031	Sieve diameters 0.062	0.125	0.250	0.500	Methods of analysis
					Clay		Silt				Sand			
				2135. Cattaraugus Creek at Gowanda, New York										
3/25/63	1830	9,030	38	3,970	23	28	39	49	60	74	85	92	97	BSWCM
3/27/63	0030	14,100	--	5,090	25	31	42	53	70	78	87	94	98	BSWCM
3/ 5/64	0845	18,100	35	5,310	25	34	45	58	73	83	92	96	99	BSWCM
3/ 5/64	0845	18,100	35	5,310	12	16	26	40	60	79	89	94	99	BSN
				2170. Tonawanda Creek at Batavia, New York										
3/27/63	1245	3,430	--	442	63	78	83	88	91	93	96	98	99	BSWCM
4/20/63	1550	824	51	1,260	48	58	75	88	96	99	100	100	100	BSWCM

OBSERVATIONS OF STREAM EROSION

Stream erosion has caused damage to highways and has removed land with recreational or agricultural value, only to leave worthless low-lying, rubbly land in its stead. To obtain a measure of the rate of streambank erosion, streambanks along three different reaches of streams were surveyed during the study. Reference pins were driven several feet from the edge of the bank, and the distances from the pins to the edge were measured before and after a period of erosion. These banks were vulnerable to sidecutting by the streams and are probably typical of actively eroding areas. The scope of the study did not allow determination of the extent of these areas of active erosion or their total quantitative sediment contribution. Likewise, no field investigations were made in relation to sheet erosion, which is a major source of sediment.

An 80-foot reach of bank of Eighteenmile Creek near Fowlerville (fig. 1) was first surveyed on November 6, 1963. The bank was about 45 feet above low stream level, and the crest of the bank was 15 to 20 feet from the stream. On November 13, 1964, the reach was remeasured showing a loss of 74 square feet of surface area. It was remeasured again on June 8, 1965, showing an additional loss of 75 square feet. In the 18 months a total of 149 square feet was lost, or about 1.9 feet per running foot of bank. As much loss occurred in the last 6 months as in the first 12 months, although most of the loss was probably during the spring of each period.

Survey pins were also set along a 380-foot reach on a sharp bend of Eighteenmile Creek near Patchin (fig. 1) on November 6, 1963. This bank was right at the stream edge and was from about 6 to 12 feet high. The line was remeasured on March 20, 1964, about 4 1/2 months later, and indicated a loss of about 1,200 square feet of surface area. This is about 3.2 square feet per running foot of bank. The opposite bank at this site was broad and less than 2 feet high and consisted primarily of coarse material that was apparently debris from the high bank.

Two survey lines were also set along Cattaraugus Creek at Zoar Bridge (fig. 1), 6 miles east of Gowanda, on November 6, 1963. One line was 108 feet long on the left bank upstream from the bridge; the other was 140 feet long on the right bank downstream from the bridge. The banks along these reaches average 6 feet in height. When the lines were revisited a year later, on November 13, 1964, all signs of the right-bank line were gone including several blazed trees. Apparently, approximately 840 square feet of land that lay between the survey line and the streambank had been eroded away, along with additional land behind the survey line. The left-bank site had lost approximately 165 square feet during the same year period. Seven months later, on June 8, 1965, one of the survey pins was missing from the upstream line after having been removed or eroded away. The stream appeared to have cut into the left bank a total of 12 to 15 feet.

Weathering and erosion of shale in streambanks have also caused local damage. For example, recent erosion in the gorge of Eighteenmile Creek (near the New York State Thruway) has required the rebuilding of part of a

local highway. The creek undercut the wall of the gorge and undermined the highway, thereby creating a danger of sudden collapse of a thick section of shale that would have carried the highway away.

Stream channel and bank erosion can be controlled by stabilizing the banks, and this can be accomplished by various methods including riprapping, grading, and seeding. However, these methods, to be effective, require a considerable amount of work and are seldom economically justified simply to save surface areas. Such methods may be warranted on the basis of both erosion prevention and sediment reduction. The several miles of streambank protection works constructed by the U.S. Soil Conservation Service and the U.S. Corps of Engineers in Buffalo, Cazenovia, and Cayuga Creek basins were justified on the basis of reducing sediment loads. One study (Parsons and others, 1964, p. 11) indicates that channel stabilization alone reduced sediment delivery in Buffalo Creek at Gardenville by 40 percent.

DEPOSITION

Some sediment deposition normally occurs whenever the velocity of a sediment-laden stream decreases. The flow and velocity of a stream decrease rapidly following the peak of a flood, at which time sediment is deposited in the stream channel. Such deposition may go unnoticed except where bars are built in valley bottoms of meandering streams such as in Cattaraugus Creek.

The velocity of stream water decreases abruptly where streams enter lakes and reservoirs, thus causing sediment deposition. In this manner, sediment is deposited at the mouths of streams entering Lake Erie. A notable example is the bar that has formed at the mouth of Cattaraugus Creek from material carried by the stream. Residential land around the mouth of the creek has been flooded in the spring when floating ice lodges on the bar and causes an ice jam that chokes the creek channel. A change in channel hydraulics is also responsible for deposition in the Buffalo River. An abrupt decrease in velocity occurs where the waters from Cazenovia, Buffalo, and Cayuga Creeks enter the deep, wide channel of the river, and at these points sediment tends to accumulate in the Buffalo River. This sediment deposition is the cause of the periodic dredging that is done by the Corps of Engineers, U.S. Army, so as to maintain the depth of the navigation channel.

Sediment deposition is a significant factor in reservoir design. Reservoirs can trap entering sediment because of the abrupt decrease in velocity that stream waters undergo as they flow into the reservoir pool. If the entering streams are heavily laden with sediment and the reservoirs are small, sediment accumulation will rapidly reduce the reservoir capacity. Such a reduction has already occurred at two reservoirs in the Erie-Niagara basin. Gowanda's water-supply reservoir on Point Peter Brook is almost completely filled with sediment and no longer provides adequate storage. The powerplant reservoir on Cattaraugus Creek at Springville has lost much of its storage space and requires sluice flushing each spring to maintain its present limited capacity.

The proportion of fluvial sediment that is deposited upon entering a reservoir is called the trap efficiency of the reservoir. If a reservoir traps 60 percent of the sediment entering it, the reservoir is said to have a trap efficiency of 60 percent. Trap efficiency is determined by the particle size of the sediment and by several reservoir characteristics among which are the reservoir's storage capacity, shape, age, outlet configuration and operation. Brune (1953) found that the overriding factor in determining trap efficiency is the capacity-inflow ratio, which is defined as the ratio of the capacity of a reservoir to the amount of annual streamflow entering it. The larger a reservoir in relation to streamflow, the more efficient it is as a sediment trap. The relationship of trap efficiency to capacity-inflow ratio is shown in figure 6. The trap efficiency of a reservoir with the small capacity-inflow ratio of 0.01 is about 45 percent. Trap efficiency increases to about 87 percent for a capacity-inflow ratio of 0.1. Therefore, for any particular site on a stream, reservoir sedimentation would be doubled if the capacity-inflow ratio were

increased from 0.01 to 0.1. However, an increase in capacity-inflow ratio from 0.01 to 0.1 represents a tenfold increase in reservoir storage capacity. It can be seen, therefore, that a small reservoir will be filled with sediment much faster.

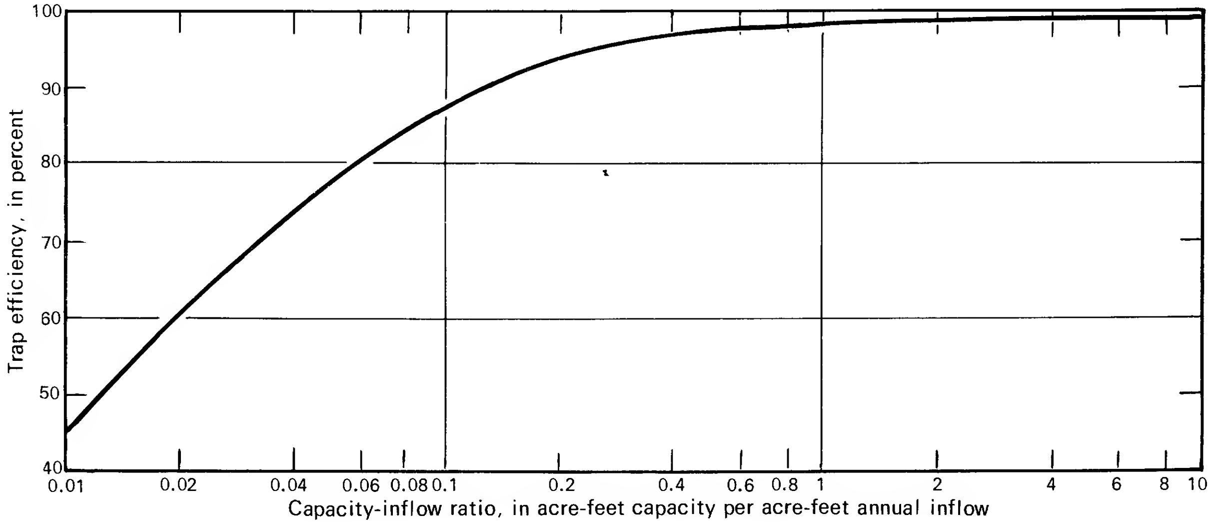


Figure 6.--Relationship of trap efficiency to the reservoir capacity-inflow ratio (from Brune, 1953).

If the annual sediment yield and flow of a stream are known or can be estimated, the sediment deposition for reservoirs of various capacities can be estimated from figure 7. For example, if the average annual sediment yield is 500 tons per square mile of drainage basin and if a reservoir is constructed with a capacity-inflow ratio of 0.01, the volume of sediment that will be deposited annually is 0.17 acre-feet per square mile of drainage basin. If the reservoir capacity is increased 10 times to give a capacity-inflow ratio of 0.1, the volume of sediment deposited annually will be about 0.34 acre-feet per square mile of drainage basin. In this manner consideration can be given to the amount of storage that will be lost due to sediment deposited throughout the life of the reservoir.

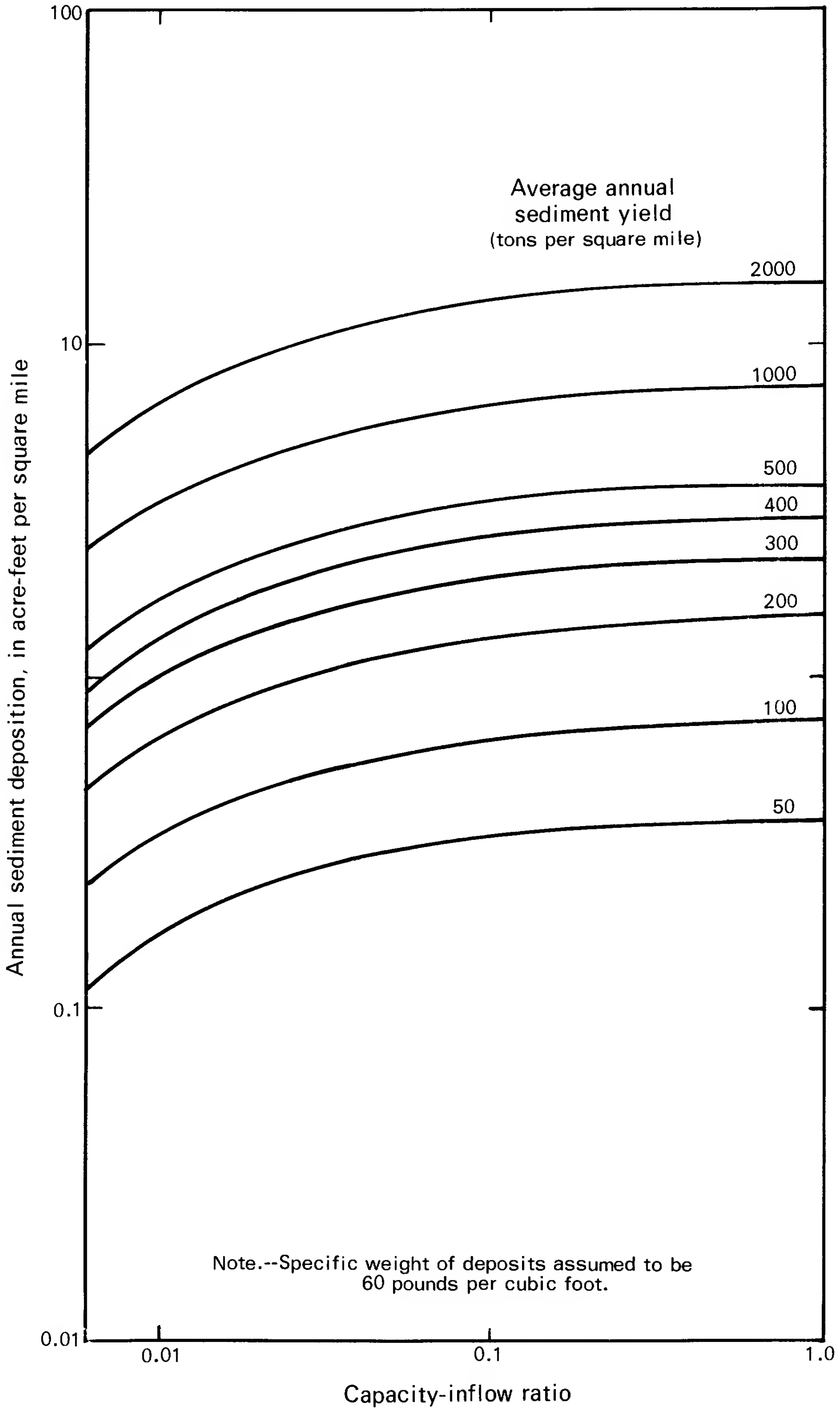


Figure 7.--Design curves for predicting sediment storage in proposed reservoirs (adapted from Brune, 1953).

SUMMARY OF PRESENT CONDITIONS

Computed annual sediment discharges for stream stations studied in the Erie-Niagara basin range from 1,100 tons per year for Little Tonawanda Creek at Linden to 610,000 tons per year for Cattaraugus Creek at Gowanda. Sediment discharge values, based on drainage area, range from 50 tons per square mile for Little Tonawanda Creek at Linden to 1,500 tons per square mile for Cazenovia Creek at Ebenezer. These differences in sediment yields result largely from the differences in availability of easily erodible glacial deposits. The highest sediment yields, on the order of 1,000 tons per square mile, occur in the upland part of the study area (fig. 1), where slopes are steep, and easily erodible glacial-lake deposits are thick and widespread.

The range in observed sediment yields also is influenced by the size of basins above the sampling stations. If observations had been made on more numerous and smaller basins, the observed range of unit yields would be larger than is indicated by data reported in this report. Conversely, if fewer and larger basins had been observed, the range in sediment yields probably would be less than indicated by data in this report and presumably would converge on the average annual sediment yield for the entire area.

Peak suspended-sediment concentrations in the range of 2,600 to 5,300 ppm (parts per million) have been observed at three stations in the Cattaraugus Creek basin, as well as at Buffalo Creek at Gardenville, Cazenovia Creek at Ebenezer, and Cayuga Creek near Lancaster. By contrast, the maximum observed concentrations for Little Tonawanda Creek at Linden, Tonawanda Creek at Rapids, and Ellicott Creek at Williamsville were only in the range of 100 to 200 ppm.

Sediment deposition has caused problems in Buffalo Harbor, at the mouth of Cattaraugus Creek, and in Point Peter Brook and Springville Power reservoirs. Programs of soil conservation and bank stabilization can and have decreased sediment contributions to the streams and, in turn, to the areas of deposition such as Buffalo Harbor. Land surface loss and highway damage are problems directly related to erosion.

Surface waters in the Erie-Niagara basin possess tremendous potential for development; however, few surface-water bodies can be developed without some considerations of sediment problems from the standpoints of treatment of turbidity or sediment deposition. In the central and southern, or upland part of the basin, more consideration should be given to sediment conditions than elsewhere when planning reservoir development for water supply, flood control, low-flow augmentation, or recreation.

RECOMMENDATIONS FOR ADDITIONAL STUDIES

Future investigations of sediment should be made in areas or at sites where water-resources developments are planned in order to better define total load and temporal variations. Basins in which glacial-lake sediments occur are most likely to yield significant quantities of sediment and, therefore, most warrant investigations of sediment discharge prior to water developments. Continued suspended-sediment observations at selected stations included in the present investigations are recommended to better define variations in suspended-sediment concentrations. Observations could be made by random sampling at intervals of 5 to 6 weeks over a period of several years at relatively small cost. More intensive sampling of storm runoff is needed also in the area of high-sediment yield to define more precisely the sediment yields of streams on which reservoirs may be constructed, so that reservoir-design information can be obtained.

SELECTED REFERENCES

Brune, G. M., 1953, Trap efficiency of reservoirs: Trans. Am. Geophys. Union, v. 34, no. 3, p. 407-426.

Colby, B. R., and Hembree, C. H., 1955, Computations of total sediment discharge, Niabrara River near Cody, Nebraska: U.S. Geol. Survey Water-Supply Paper 1357, 187 p.

Colby, B. R., Hembree, C. H., and Rainwater, F. H., 1956, Sedimentation and chemical quality of surface waters in the Wind River Basin, Wyoming: U.S. Geol. Survey Water-Supply Paper 1373, 336 p.

Harding, W. E., and Gilbert, B. K., 1968, Surface-water in the Erie-Niagara basin, New York: New York Water Resources Comm., basin planning rept. ENB-2. (In press)

Keller, F. J., and Gilbert, B. K., 1966, The occurrence and characteristics of fluvial sediment in the Genesee River basin -- a reconnaissance: U.S. Army, Corps of Engineers, Genesee River Basin Comprehensive Study of Water and Related Land Resources, Attachment A, App. K, 23 p.

Miller, C. R., 1951, Analysis of flow duration, sediment-rating curve method of computing sediment yield: U.S. Bur. of Reclamation rept., 55 p.

Parsons, D. A., Apmann, R. P., and Decker, G. H., 1964, The determination of sediment yields from flood water samplings: Internat. Union of Geodesy and Geophysics pub. no. 65, p. 7-15.

Rainwater, F. H., 1961, Stream composition of the conterminous United States: U.S. Geol. Survey Hydrol. Atlas HA-61.

Wark, J. W., Keller, F. J., and Feltz, H. F., 1961, Reconnaissance of sedimentation and chemical quality of surface water in the Potomac River basin: U.S. Army, Corps of Engineers Potomac River Basin rept., App. H., v. VII, 73 p.

Table 4.--Suspended-sediment measurements in the Erie-Niagara basin

All suspended-sediment measurements, made by the U.S. Geological Survey during the course of the Erie-Niagara basin study are included in this table. Additional measurements used in the computation of the estimated annual yields for Buffalo Creek at Gardenville, Cayuga Creek near Lancaster, and Cazenovia Creek at Ebenezer supplied by the U.S. Agricultural Research Service are also included. The latter data are indicated by footnote in the table. Water discharges and sediment concentration were rounded to three significant figures by the U.S. Geological Survey. All sediment discharges were calculated by the U.S. Geological Survey. The numbers preceding the stream name and location is the waters index number used and explained in New York State Department of Health stream classification reports. The number following the stream name and location is U.S. Geological Survey's surface-water station number which is explained in its annual surface-water records report.

Date of collection	Time (24-hour)	Water temperature (°F)	Discharge (cfs)	Suspended sediment: Concentration (ppm)	Suspended sediment: Discharge (tons per day)
E23(54.7) Cattaraugus Creek near Arcade 2134.1					
3/20/63	1230	32	848	90	206
3/25/63	1550	38	1,540	875	3,640
3/26/63	1030	36	1,540	400	1,660
3/27/63	1040	34	1,500	916	3,710
3/ 4/64	1500	36	311	289	243
3/ 4/64	2145	--	1,400	885	3,340
3/ 5/64	0645	--	3,270	1,240	10,900
3/ 5/64	1945	33	2,290	706	4,360
3/ 6/64	0810	32	812	111	243
3/25/64	2105	38	765	103	213
3/26/64	0820	39	624	45	76
E23-48(0.6) Elton Creek at The Forks 2134.2					
3/20/63	1305	--	550	430	638
3/25/63	1420	--	1,340	2,360	8,540
3/26/63	1125	38	1,150	1,240	3,850
3/27/63	0945	--	1,640	2,220	9,830
3/27/63	1315	39	1,150	1,390	4,320
4/ 4/63	1315	42	1,170	677	2,140
4/20/63	0945	50	696	532	1,000
3/ 5/64	0715	33	3,210	3,940	34,100
3/25/64	2135	39	426	362	416
3/26/64	0845	39	450	321	390

Table 4.--Suspended-sediment measurements in the Erie-Niagara basin (Continued)

Date of collection	Time (24-hour)	Water temperature (°F)	Discharge (cfs)	Suspended sediment: Concentration (ppm)	Suspended sediment: Discharge (tons per day)
E23-33(0.4) Buttermilk Creek near Springville 2134.5					
4/ 4/63	1240	--	168	139	63
4/20/63	1015	49	241	218	142
3/ 4/64	1540	32	550	2,150	3,190
3/ 4/64	2020	33	1,000	2,450	6,620
3/ 5/64	0800	36	2,440	3,440	22,700
3/ 5/64	1900	34	826	1,310	2,920
3/25/64	2215	38	187	240	121
3/26/64	0915	39	194	190	100
E23-20(14.4) South Branch Cattaraugus Creek near Otto 2134.9					
3/26/63	1245	46	366	459	454
3/26/63	1610	46	538	1,830	2,660
3/26/63	1815	44	630	1,140	1,940
3/ 4/64	1935	--	1,180	1,090	3,470
3/ 5/64	1820	33	725	620	1,210
E23(17.4) Cattaraugus Creek at Gowanda 2135					
3/21/63	1630	33	2,440	283	1,860
3/24/63	1915	40	4,520	3,030	37,000
3/25/63	1130	43	4,980	1,000	13,500
3/25/63	1830	38	9,000	3,970	96,500
3/26/63	1000	40	7,520	2,220	45,100
3/26/63	1630	42	9,450	3,200	81,600
3/26/63	2100	39	13,000	5,310	186,000
3/27/63	0030	--	14,100	5,090	194,000
3/27/63	0725	--	11,600	3,800	119,000
3/27/63	1645	44	6,460	1,990	34,700
3/ 5/64	0845	35	18,100	5,310	259,000
3/ 5/64	1720	34	16,200	4,080	178,000
3/ 6/64	0910	32	4,600	1,490	18,500
3/26/64	1105	39	2,780	479	3,600
E23-6(0.9) Clear Creek near Iroquois 2140.1					
3/26/63	1400	--	645	449	782
3/26/63	2145	--	1,290	1,630	5,680
4/19/63	2225	56	124	175	58

Table 4.--Suspended-sediment measurements in the Erie-Niagara basin (Continued)

Date of collection	Time (24-hour)	Water temperature (° F)	Discharge (cfs)	Suspended sediment Concentration (ppm)	Suspended sediment Discharge (tons per day)
E20(2.2) Big Sister Creek at Evans Center 2140.6					
4/19/63	2305	56	196	299	158
E13(15.3) Eighteenmile Creek at North Boston 2142					
3/18/63	1430	33	730	610	1,200
3/20/63	1440	33	626	311	526
3/23/63	1840	--	169	116	53
3/25/63	0825	42	685	340	629
3/25/63	1200	40	713	370	712
3/25/63	2025	34	1,430	1,480	5,710
3/26/63	0825	39	830	470	1,050
3/30/63	1030	43	1,070	1,370	3,960
4/19/63	2120	56	587	1,520	2,410
3/ 4/64	1735	33	854	1,520	3,500
3/ 5/64	1020	37	1,910	1,610	8,300
3/ 5/64	1630	35	1,290	1,310	4,560
3/25/64	2245	39	266	160	115
3/26/64	0945	39	413	188	210
E-13-4(2.9) South Branch Eighteenmile Creek at Eden Valley 2142.3					
4/19/63	2135	55	688	1,380	2,560
E13(0.5) Eighteenmile Creek near Highland-on-the-Lake 2142.4					
3/26/63	1330	42	2,430	386	2,530
4/19/63	2350	55	1,160	852	2,670
E2(3.5) Smoke Creek at Lackawanna 2142.5					
8/ 7/63	1405	--	257	648	450
E1(31.8) Buffalo Creek near Wales Hollow 2144					
3/20/63	0930	--	≠1,050	246	697
3/25/63	1405	38	1,260	243	827
4/20/63	0810	51	750	336	680
3/ 4/64	2310	--	≠2,830	1,170	8,940
3/ 5/64	1440	35	3,160	961	8,200
3/ 6/64	1130	33	418	81	91
3/26/64	0015	38	554	128	191
3/26/64	1310	38	660	127	226

≠ Estimated.

Table 4.--Suspended-sediment measurements in the Erie-Niagara basin (Continued)

Date of collection	Time (24-hour)	Water temperature (° F)	Discharge (cfs)	Suspended sediment: Concentration (ppm)	Suspended sediment: Discharge (tons per day)
E1(10.4) Buffalo Creek at Gardenville 2145					
2/19/61	1226	--	2,150	*1,290	7,490
2/19/61	1341	--	2,160	* 910	5,310
2/19/61	1456	--	2,130	* 660	3,800
2/19/61	1637	--	2,050	* 530	2,930
2/23/61	1012	--	1,050	* 400	1,130
2/23/61	1117	--	1,150	* 420	1,300
2/23/61	1223	--	1,450	* 540	2,110
2/23/61	1322	--	1,700	* 650	2,980
2/23/61	1433	--	1,800	* 780	3,790
2/23/61	1543	--	1,870	* 970	4,900
2/23/61	1851	--	2,650	*1,650	11,800
2/23/61	2005	--	2,700	*1,750	12,800
2/23/61	2140	--	2,750	*1,450	10,900
2/23/61	2250	--	2,770	*1,460	10,900
4/25/61	0717	--	6,700	*2,470	44,700
4/25/61	0826	--	6,720	*2,170	39,400
4/25/61	0931	--	6,800	*1,880	34,500
4/25/61	1106	--	6,400	*1,500	25,900
8/ 2/61	1152	--	160	* 350	151
8/ 2/61	1313	--	170	* 340	156
8/ 2/61	1424	--	180	* 230	112
8/ 2/61	1545	--	4,000	*2,480	26,800
8/ 2/61	1740	--	3,150	*4,390	37,300
8/ 2/61	1842	--	2,050	*3,160	17,500
3/17/63	1531	--	3,800	*1,520	15,600
3/17/63	1720	33	3,900	*2,020	21,300
3/17/63	1907	33	4,260	*2,260	26,000
3/17/63	2030	33	4,300	*3,050	35,400
3/17/63	2154	33	4,350	*5,150	60,500
3/17/63	2326	--	4,450	*5,240	63,000
3/18/63	0048	--	4,500	*5,210	63,300
3/25/63	1743	42	1,920	* 362	1,880
3/25/63	1854	--	2,600	* 558	3,920
3/25/63	2030	40	3,020	*1,080	8,810
3/25/63	2148	--	3,060	*1,480	12,200
3/25/63	2230	41	3,100	*1,550	13,000
3/25/63	2315	38	3,100	*1,670	14,000
3/26/63	0006	40	3,110	*1,550	13,000
3/26/63	0035	37	3,110	*1,620	13,600
3/26/63	0113	37	3,120	*1,690	14,200
3/26/63	0137	39	3,130	*1,450	12,200
3/26/63	0256	37	2,840	*1,280	9,820

Table 4.--Suspended-sediment measurements in the Erie-Niagara basin (Continued)

Date of collection	Time (24-hour)	Water temperature (°F)	Discharge (cfs)	Suspended sediment: Concentration (ppm)	Suspended sediment: Discharge (tons per day)
E1(10.4) Buffalo Creek at Gardenville 2145--Continued					
4/ 4/63	0016	--	1,090	* 750	2,210
4/ 4/63	0133	53	1,980	* 887	4,740
4/ 4/63	0252	53	2,640	*1,140	8,120
4/ 4/63	0358	52	2,660	*1,300	9,340
4/ 4/63	0517	51	2,700	*1,510	11,000
4/ 4/63	0617	51	2,710	*1,090	7,980
4/ 4/63	0910	45	2,270	995	6,100
7/29/63	1814	--	830	* 846	1,900
7/29/63	1953	--	535	* 438	633
7/29/63	2052	--	425	* 362	415
8/ 7/63	1203	--	1,280	* 478	1,650
8/ 7/63	1205	67	1,290	406	1,410
8/ 7/63	1352	--	960	* 384	995
8/ 7/63	1516	--	1,140	* 321	988
8/14/63	0937	--	1,920	* 789	4,090
8/14/63	1058	--	1,800	* 742	3,610
8/14/63	1108	--	1,770	* 650	3,110
8/14/63	1249	--	1,580	* 611	2,610
3/ 5/64	1130	35	5,840	1,620	25,500
3/ 5/64	1345	39	1,470	194	770
* Data furnished by Soil Conservation Service.					
E1-6-7(2.9) Little Buffalo Creek at East Lancaster 2149.8					
4/19/63	2320	57	150	466	189
8/ 7/63	1035	--	96	225	58
E1-6(11.0) Cayuga Creek near Lancaster 2150					
2/19/61	1253	--	1,650	* 630	2,810
2/19/61	1407	--	1,620	* 730	3,190
2/19/61	1525	--	1,540	* 520	2,160
2/19/61	1706	--	1,450	* 390	1,620
2/23/61	0917	--	960	* 820	2,120
2/23/61	1033	--	1,130	* 910	2,780
2/23/61	1136	--	1,450	*1,170	4,580
2/23/61	1241	--	1,670	*1,360	6,130
2/23/61	1344	--	2,130	*1,570	9,030
2/23/61	1457	--	2,500	*2,240	15,100
2/23/61	1800	--	3,150	*2,090	17,800
2/23/61	1917	--	3,040	*1,810	14,800

Table 4.--Suspended-sediment measurements in the Erie-Niagara basin (Continued)

Date of collection	Time (24-hour)	Water temperature (°F)	Discharge (cfs)	Suspended sediment: Concentration (ppm)	Suspended sediment: Discharge (tons per day)
El-6(11.0) Cayuga Creek near Lancaster 2150--Continued					
2/23/61	2027	--	2,950	*1,540	12,300
2/23/61	2202	--	2,700	*1,260	9,180
4/25/61	0727	--	4,850	*1,590	20,800
4/25/61	0847	--	4,250	*1,300	14,900
4/25/61	1001	--	3,750	*1,060	10,700
4/25/61	1128	--	3,750	*1,090	11,000
8/ 2/61	1223	--	115	* 150	46
8/ 2/61	1335	--	115	* 230	71
8/ 2/61	1451	--	115	* 520	161
8/ 2/61	1616	--	115	* 360	112
3/17/63	1454	36	4,730	*2,490	31,800
3/17/63	1756	33	5,800	*1,490	23,300
3/17/63	1831	33	6,090	*1,500	24,700
3/17/63	2001	33	6,240	*1,400	23,600
3/17/63	2123	33	5,940	*1,390	22,300
3/17/63	2304	33	5,500	*2,680	39,800
3/18/63	0026	--	5,020	*1,700	23,000
3/25/63	1717	42	750	* 665	1,350
3/25/63	1836	--	1,020	*1,390	3,830
3/25/63	2006	44	1,150	*1,960	6,080
3/25/63	2123	--	1,140	*1,820	5,600
3/25/63	2202	48	1,100	*1,220	3,620
3/25/63	2337	45	930	*1,050	2,640
3/26/63	0008	42	875	*1,080	2,550
3/26/63	0112	44	765	*1,150	2,380
3/26/63	0229	43	645	* 962	1,680
4/ 3/63	2354	56	440	* 154	183
4/ 4/63	0106	54	475	* 607	778
4/ 4/63	0229	52	1,040	*1,280	3,590
4/ 4/63	0333	51	1,340	*1,680	6,080
4/ 4/63	0452	50	1,330	*1,780	6,390
4/ 4/63	0554	49	1,010	*1,460	3,980
7/29/63	1734	66	675	*1,570	2,860
7/29/63	1927	--	520	* 938	1,320
7/29/63	2023	--	455	* 633	778
8/ 7/63	1015	--	527	308	438
8/ 7/63	1139	65	560	* 491	742
8/ 7/63	1322	65	480	* 753	976
8/ 7/63	1448	67	400	* 526	568
8/14/63	1004	60	920	*1,340	3,330
8/14/63	1129	61	920	*1,290	3,200
8/14/63	1321	61	893	* 929	2,240
3/ 5/64	1205	37	3,540	1,100	10,500

* Data furnished by Soil Conservation Service.

Table 4.--Suspended-sediment measurements in the Erie-Niagara basin (Continued)

Date of collection	Time (24-hour)	Water temperature (°F)	Discharge (cfs)	Suspended sediment Concentration (ppm)	Suspended sediment Discharge (tons per day)
E1-4-15(0.5) West Branch Cazenovia Creek near East Aurora 2152.5					
3/25/63	0940	36	938	186	471
4/19/63	2230	56	775	1,360	2,840
3/ 5/64	1600	34	1,160	1,820	5,700
3/26/64	1220	39	--	135	--
E1-4-14(8.1) East Branch Cazenovia Creek at South Wales 2153.5					
3/20/63	1050	--	--	158	--
3/25/63	1300	36	663	252	451
4/20/63	0900	50	346	150	140
3/ 4/64	2230	33	1,150	1,140	3,540
3/ 5/64	1500	36	1,410	1,090	4,150
3/26/64	0045	37	254	57	39
3/26/64	1250	39	307	56	46
E1-4(4.1) Cazenovia Creek at Ebenezer 2155					
2/19/61	1201	--	4,200	*1,790	20,300
2/19/61	1318	--	4,000	*1,650	17,800
2/19/61	1435	--	3,600	*1,390	13,500
2/19/61	1525	--	3,400	*1,130	10,400
2/23/61	0945	--	1,260	* 910	3,100
2/23/61	1101	--	1,500	* 930	3,770
2/23/61	1204	--	1,650	* 980	4,360
2/23/61	1306	--	1,830	*1,140	5,630
2/23/61	1411	--	2,100	*1,330	7,540
2/23/61	1526	--	2,330	*1,360	8,560
2/23/61	1832	--	2,950	*1,970	15,700
2/23/61	1950	--	3,050	*1,990	16,400
2/23/61	2140	--	3,100	*1,950	16,300
2/23/61	2235	--	3,090	*2,160	18,000
4/25/61	0627	--	3,350	*2,250	20,400
4/25/61	0806	--	3,500	*2,280	21,500
4/25/61	0911	--	3,550	*2,000	19,200
4/25/61	1026	--	3,600	*1,730	16,800
8/ 2/61	1131	--	180	*1,040	505
8/ 2/61	1251	--	175	*1,500	709
8/ 2/61	1401	--	1,360	*1,820	6,680
8/ 2/61	1524	--	1,200	*1,600	5,180
8/ 2/61	1717	--	1,700	*1,730	7,940
8/ 2/61	1825	--	1,500	*1,400	5,670
3/17/63	1558	34	5,100	*2,190	30,200

Table 4.--Suspended-sediment measurements in the Erie-Niagara basin (Continued)

Date of collection	Time (24-hour)	Water temperature (°F)	Discharge (cfs)	Suspended sediment: Concentration (ppm)	Suspended sediment: Discharge (tons per day)
E1-4(4.1) Cazenovia Creek at Ebenezer 2155--Continued					
3/17/63	1751	33	5,400	*2,580	37,600
3/17/63	1920	33	5,500	*2,170	32,200
3/17/63	2051	33	5,550	*1,880	28,200
3/17/63	2231	33	5,600	*2,670	40,400
3/17/63	2354	--	5,420	*3,280	48,000
3/20/63	1630	33	2,020	298	1,620
3/25/63	1803	41	2,670	* 743	5,360
3/25/63	1928	--	2,980	*1,710	13,800
3/25/63	2048	39	3,320	*1,560	14,000
3/25/63	2217	--	3,440	*1,630	15,100
3/25/63	2259	38	3,540	*1,920	18,400
3/25/63	2333	37	3,540	*2,350	22,500
3/26/63	0038	37	3,610	*1,630	15,900
3/26/63	0056	36	3,610	*1,420	13,800
3/26/63	0157	36	3,550	*1,470	14,100
4/ 4/63	0039	51	2,000	*1,270	6,860
4/ 4/63	0159	49	2,800	*1,880	14,200
4/ 4/63	0305	49	3,240	*1,640	14,300
4/ 4/63	0425	48	3,550	*1,670	16,000
4/ 4/63	0529	47	3,720	*1,570	15,800
4/ 4/63	1005	46	2,260	916	5,590
8/ 7/63	1040	65	1,570	1,990	8,440
8/ 7/63	1231	65	965	*1,800	4,690
8/ 7/63	1412	66	630	*1,030	1,750
8/ 7/63	1535	68	480	* 829	1,070
8/14/63	0921	60	2,320	* 889	5,570
8/14/63	1038	60	2,170	* 630	3,690
8/14/63	1226	61	1,820	* 471	2,310
3/ 5/64	1100	35	6,190	1,970	32,900
3/26/64	1415	39	1,500	159	644
* Data furnished by Soil Conservation Service.					
0158-15(6.8) Scajaquada Creek at Buffalo 2162					
3/21/63	1350	--	60	74	12
4/ 4/63	0845	--	122	520	171
4/19/63	1940	57	558	3,270	4,930
4/19/63	2115	--	718	3,300	6,400

Table 4.--Suspended-sediment measurements in the Erie-Niagara basin (Continued)

Date of collection	Time (24-hour)	Water temperature (° F)	Discharge (cfs)	Suspended sediment: Concentration (ppm)	Suspended sediment: Discharge (tons per day)
0158-12(100.6) Tonawanda Creek near Johnsonburg 2164					
3/26/63	0850	34	450	304	369
4/20/63	0730	50	240	187	121
3/ 5/64	1400	34	1,020	1,640	4,520
3/25/64	2030	38	170	131	60
3/26/64	0755	37	154	94	39
0158-12-32(10.5) Little Tonawanda Creek at Linden 2165					
3/26/63	0740	36	379	58	59
3/27/63	1330	40	256	47	32
4/ 2/63	1000	--	107	16	4.6
4/ 4/63	0605	47	469	117	148
4/ 4/63	1530	--	165	35	16
4/19/63	2305	--	111	109	33
4/20/63	0645	51	126	42	14
0158-12(68.7) Tonawanda Creek at Batavia 2170					
3/18/63	1905	--	4,420	382	4,560
3/19/63	1350	34	2,560	314	2,170
3/20/63	0710	--	1,680	195	884
3/22/63	1035	33	890	189	454
3/25/63	0820	37	1,210	585	1,910
3/25/63	2345	--	1,830	230	1,140
3/26/63	0645	--	2,580	474	3,300
3/27/63	1245	--	3,420	442	4,080
3/27/63	2315	--	2,500	242	1,630
3/28/63	1045	--	1,630	192	845
4/ 4/63	0645	--	840	236	535
4/ 4/63	1930	--	1,820	575	2,820
4/20/63	1550	51	824	1,260	2,800
3/ 4/64	1115	32	380	111	114
3/ 5/64	1315	35	3,430	1,490	13,800
3/ 6/64	1420	34	3,160	310	2,640
3/25/64	1935	42	780	388	817
3/26/64	0700	38	1,420	465	1,780
3/26/64	1635	40	1,560	276	1,160
3/27/64	0745	32	1,010	152	414

Table 4.--Suspended-sediment measurements in the Erie-Niagara basin (Continued)

Date of collection	Time (24-hour)	Water temperature (° F)	Discharge (cfs)	Suspended sediment	
				Concentration (ppm)	Discharge (tons per day)
0158-12(46.9) Tonawanda Creek near Alabama 2175					
3/21/63	1020	--	2,130	152	874
3/22/63	0620	32	1,580	113	482
3/27/63	1815	43	3,110	335	2,810
3/28/63	0645	--	3,110	267	2,240
3/29/63	0745	43	1,420	153	587
4/ 5/63	0820	40	1,850	358	1,790
0158-12(19.5) Tonawanda Creek at Rapids 2180					
3/19/63	0925	32	4,210	57	648
3/19/63	1655	32	4,600	111	1,380
3/21/63	1150	33	4,470	87	1,050
3/22/63	0745	33	3,770	84	855
3/26/63	1010	--	1,860	74	372
3/27/63	1715	44	2,890	197	1,540
3/28/63	0745	--	3,190	147	1,270
3/28/63	1830	44	3,340	190	1,710
3/29/63	1630	47	3,040	113	928
3/ 6/64	1245	32	2,150	112	650
3/26/64	1530	39	1,690	170	776
3/27/64	1050	33	2,070	186	1,040
0158-12-1(28.8) Ellicott Creek at Mill Grove 2184.5					
3/19/63	1750	32	440	96	114
3/20/63	0805	--	768	152	315
3/22/63	0930	33	157	26	11
3/25/63	0920	--	390	112	118
3/26/63	0920	--	354	90	86
3/27/63	1530	43	282	54	41
4/ 4/63	0730	51	538	416	643
4/ 4/63	1710	45	400	133	144
4/20/63	1400	51	294	76	60
3/ 5/64	1230	35	1,340	227	821
3/ 6/64	1205	35	190	38	19
3/26/64	1445	39	714	151	291
3/27/64	0830	33	156	38	16

Table 4.--Suspended-sediment measurements in the Erie-Niagara basin (Continued)

Date of collection	Time (24-hour)	Water temperature (° F)	Discharge (cfs)	Suspended sediment Concentration (ppm)	Suspended sediment Discharge (tons per day)
0158-12-1(14.1) Ellicott Creek at Williamsville 2185					
3/19/63	0830	32	1,240	29	97
3/21/63	1310	34	772	24	50
3/22/63	0835	33	345	21	20
3/25/63	1005	39	425	59	68
3/25/63	2135	43	540	60	87
3/26/63	1115	--	498	50	67
3/27/63	1600	45	464	30	38
4/ 4/63	1745	47	387	101	106
4/ 5/63	0950	41	453	60	73
4/20/63	1255	55	716	99	191
8/ 7/63	1325	69	324	73	64
8/ 7/63	1805	--	270	44	32